the Energy to Lead

GTI – Addressing Methane Emissions

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GTI at a Glance…

- Not-for-profit research, with 70+ year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2, 28 specialized labs
  - Staff of 250; all fields of sscience and engineering
- $60+ million in revenue
- >1200 patents
- >500 products/processes

Flex-Fuel Test Facility

Offices & Labs

Energy & Environmental Technology Center

Potential Dimensions to SNIFFER Problem Statement

"If I had an hour to solve a problem, I'd spend the first 55 minutes defining it"

Albert Einstein

> Detection
  - Spatial Scale - length, area
  - Temporal - chronic/acute; on-line/periodic/as-needed
  - Intensity - concentration range (ppb-%); total amount
  - Discrimination/differentiation - methane, bio-methane, natural gas

> Purpose
  - Quantification – emphasis on how much
  - Remediation – emphasis on source location

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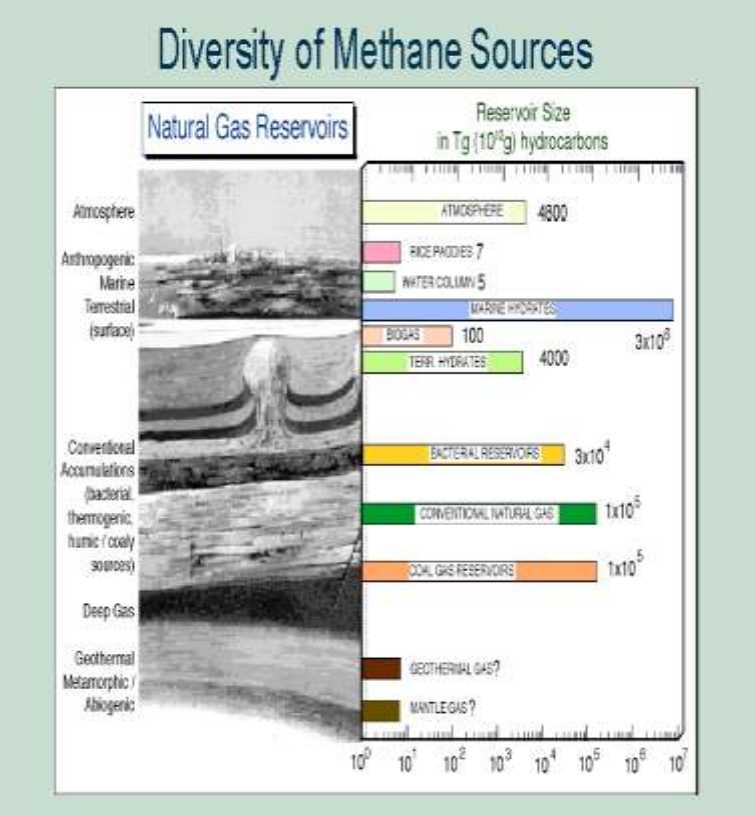
Which methane molecules are we targeting?

Natural gas one of many sources of atmospheric methane



Methane sources

• **Natural sources**	**145–260 Tg/a**
• Wetlands	100–231
• Termites	20–29
• Oceans	4–15
• Hydrates	4–5
• Geological sources	4–14
• Wild animals	15
• Wildfires	2–5
• **Anthropogenic sources**	**264–428 Tg/a**
• Energy & industry (fossil fuels)	74–106
• Landfills & waste	35–69
• Ruminants	76–92
• Rice agriculture	31–112
• Biomass burning	14–88
• **Total sources**	**503–610 Tg/a**

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Selected Past GTI Natural Gas Methane Emissions Studies

- "Unaccounted-for Gas" Studies for Sempra, PG&E, and California Energy Commission
  - 1990, 1993; 11 volumes
  - Intent was identification of causes; UAF 1.2%; "leaks" < 10% of UAF
- GRI/EPA Methane Emission Study
  - 1994/96; 22 volumes
  - "National inventory", from well to burner tip, is 1.4+/-0.5%; half from T&D
  - "Emission factor" approach which have high uncertainty due to limited datasets
  - Outdated, but still basis for EPA GHG inventory and reporting rule
  - ***Need to evolve from "national" to "company-specific" data***
- Fugitive Emission Modeling at Wellhead
  - 1993 GRI/API Western wells, 50% of total wells; 90% of production
  - 1995 GRI Eastern wells, 50% of total wells; 10% of production
- Tropospheric Methane Modeling

Defining the Problem:
More Accurate Emissions Information

- GTI is:
  - Developing a methodology for calculating methane emissions that will provide an increased level of accuracy
  - Securing appropriate industry partners to provide the technical validation of these methodologies
  - Coordinating work with AGA, EPA, and other appropriate stakeholders
- Method is based on leak measurements made at the surface using current technology, Hi-Flow Sampler
- Emission estimates will be based on leak rates and company specific leak records

Identifying Solutions: Example Methane RD&D Projects

- Commercial leak detection tools based on filtered infra-red detection
  - Optical Methane Detector
  - Portable Methane Detector
  - Ethane Detector
- LLC Remote Leak Survey Tool
- Isotopic Discrimination - GYRO
- MEMs Methane Sensor

Optical Methane Detector (OMD™)

- Optical system to improve leak survey speed
  - Gas distribution, transmission and gathering pipelines
- OMD mounted on the front of a survey vehicle
  - Infrared-based technology; No moving parts
  - Specific to methane detection
  - 10,000 measurements per second
  - Sensitivity of 1ppm at 25 mph
- Commercially available through Heath Consultants

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Portable Methane Detector (PMD)

- Develop Portable Methane Detector based on optical method; Reduce size for walking survey/hand-held unit
- Sensitive to methane detection only
- Dual low level (ppm) and high level (% gas) operation in one unit
- Commercially available through Sensit Technologies

Ethane-Only Detector: IR Ethane Detector (IRed)

- Discriminate Natural Gas Leak from other sources of Methane
- Portable instrument for field application
- Detect 250-500 ppb ethane levels in small plumes (reading 20-50 ppm methane)
- Based on and integrated with PMD platform
- Will be commercially available through Sensit Technologies

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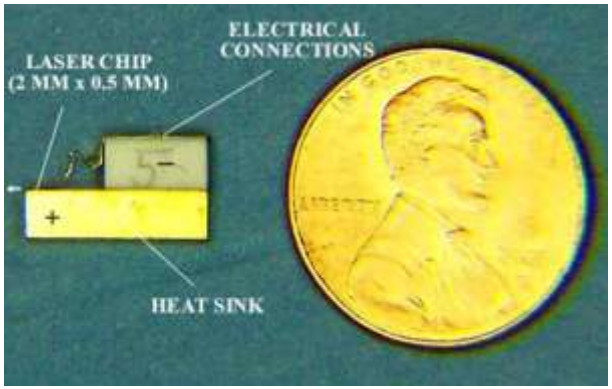
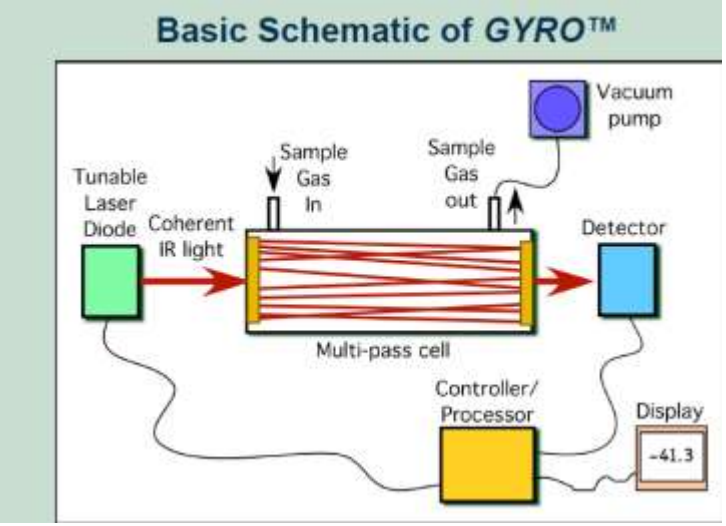
Laser Line-scan Camera (LLC) Remote Leak Survey Tool

- Originally conceived for aerial surveys of gas transmission pipelines
- Benefits from significant advances in Naval Research Labs's interband cascade laser (ICL)
- Completed and field tested prototype
  - 10 ppm sensitivity at a distance of 30 m
  - Vehicle motion up to 15 mph, potentially higher



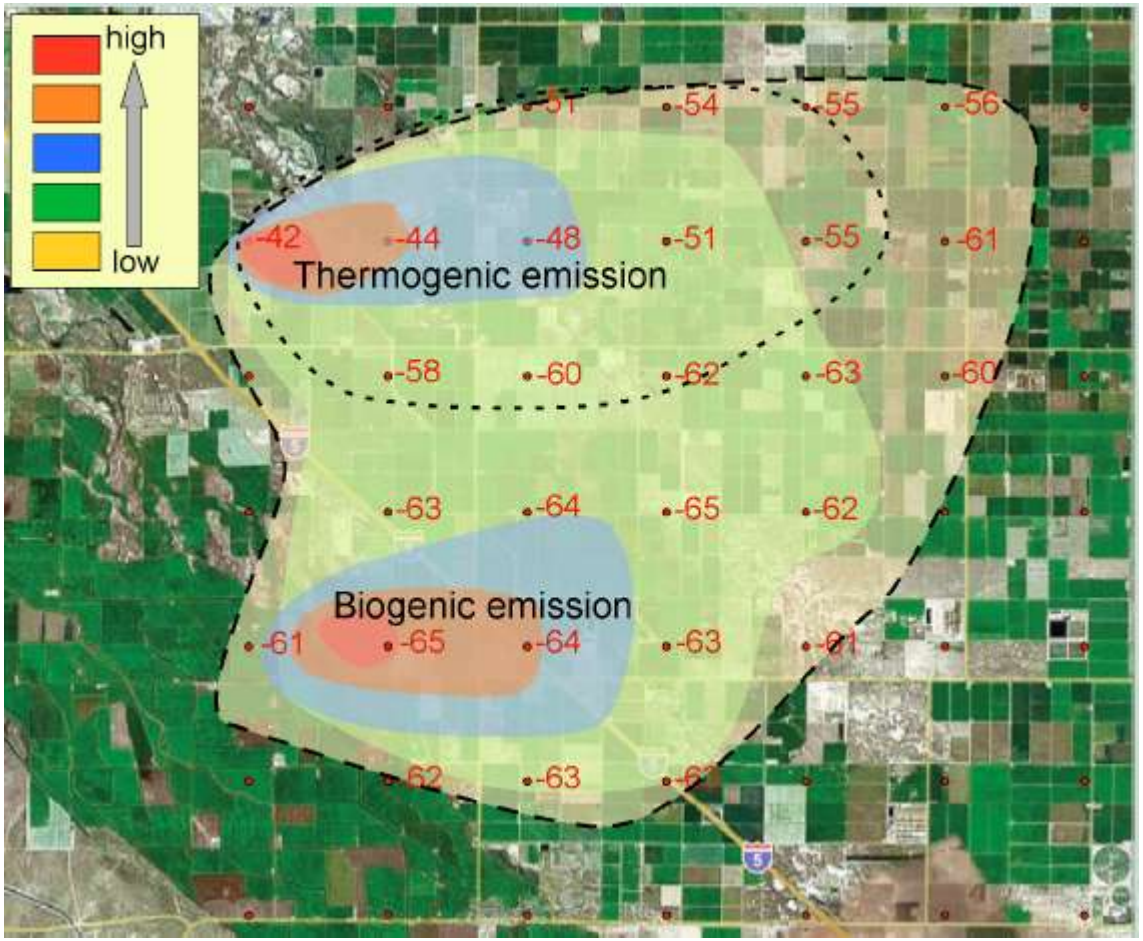
GYRO – Measurement and Source Differentiation of Methane

- GYRO: developed by Isometric Instruments
  - Demonstrated continuous field measurements of methane isotope ratios and concentrations with CEC
    - Allowed for measurement and differentiation of various primary methane-emitting activities in California



Example – GYRO Sensor Grid for Detection and Discrimination

- Fixed and mobile sensors
- Measure concentration and isotopes
- Provide gross spatial resolution for further refinement



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MEMS Methane Sensor

- KWJ Engineering's Screen Printed Electrochemical (SPEC™) SENSOR and MEMS NanoSensor™ platforms
  - Robust (no drift, no calibration, no consumables)
  - Low power requirements (<35 mW)
  - Speed of Response (from sub millisecond)
  - Sensitivity (0.1%CH_4)
  - Selective (compensates for temperature and relative humidity)
  - Stability (>30 billion measurements)
- Applications
  - Residential Home Monitoring
  - Smart Phone Integration

Suggested Next Steps

- Define the problem
  - Methane, natural gas sources, etc
- Identify the data/technology gap(s)
  - Better data for natural gas sources
  - Better instrumentation
  - Broader deployment/data gathering/system monitoring
- Develop potential solutions